

Potential Research on Energy Conservation and Emission Reduction of IGCC Technology in the Power Industry

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Abstract

China is a country mainly based on thermal power. Coal-fired power plants account for about 80% of total power generation capacity each year. It will inevitably lead to a large amount of pollutant emissions with coal combustion. Therefore, it is particularly important in the promotion of IGCC technology. On the basis of the power plant used by IGCC technology and through the use of development methodology, it can be carried out a research into the environmental benefit and economic benefit. The purpose is to comprehend the superiority of IGCC to provide better technical reference technology on energy conservation and emissions reduction in electric power industry. According to the calculation of 250MW IGCC plant, it can save 227,763 tons of coal, and 464,035 tons of CO₂ emission per year. IGCC power plant on the environmental and economic benefits is essential to the future development of electric power industry.

Keywords

Thermal Power; Pollutant Emissions Reduction; IGCC Technology; Energy Conservation and GHG Emission Reduction; Potential Research

Introduction

Coal is China's most important traditional energy. The basic characteristic of China's energy constitute is rich coal, lean oil, less gas. If we convert all kinds of resources into standard coal, coal resources accounts for more than 85% of the total reserves^[1]. At the same time, China is mainly depend on coal-fired power, thermal power generation accounts for over 80% of the total generating capacity each year, the application of a large number of coal resources in China results in the greenhouse gas emissions seriously. In answer to the call of national energy conservation and emission reduction, and ensure the effective implementation of the sustainable development strategy, developing advanced science and technology is particularly important in the use of coal efficiently and reduction of

greenhouse gas emissions and integrated gasification combined cycle (IGCC) power generation technology has the epoch-making significance. But IGCC technology in China is on the initial stage with a lot of uncertainty. This topic is based on IGCC technology using independent research of CO₂ reduction calculation methodology to the project reducing the emissions of CO₂ calculation. At the same time, further carry on the environmental benefit and economic benefit. Through this research, it can be directly seen the change in the environmental benefit and energy saving in using IGCC power plant technology. Further research and vigorously promotion on the IGCC technology will be taking profound significance in the future.

The Development of a Baseline Methodology

The calculation methodology of carbon dioxide emission reductions for IGCC technology include the power supply part of the calculation of the CO₂ emission reductions and the heating part of the calculation of the CO₂ emission reductions^[2], hereby, we introduce respectively:

Power Supply Part of the Development of the Methodology

1) The Calculation of the Emissions of the Project

CO₂ emissions from the burning of fossil fuels using power plant project with IGCC technology used in the power generation process of should be calculated using the following formula:

$$PE_e = \left[\sum_i FF_{i,e} \times NCV_{i,e} \right] \times EF_{FF,ge,CO_2} \quad 1)$$

Wherein: PE_e : the amount of CO₂ emissions from the burning of fossil fuels in the power supply project (tCO₂); $FF_{i,e}$: Project activity power supply with the total amount of the i-type fuel

(kg or m^3); $NCV_{i,e}$: Units of the i-type fuel net calorific value (GJ/kg or GJ/m^3); EF_{FF,ge,CO_2} : CO_2 emissions factor of Project activities powered fuel (tCO_2/GJ).

2) The Calculation of Emissions of the Baseline

CO_2 emissions calculation of the baseline project based on electricity generated by fossil fuel in power plants using by the major fossil fuel type ($EG_{PJ,m}$) multiplied by the baseline CO_2 emission factor (EF_{BL,e,CO_2}), the formula is as follows:

$$BE_e = EG_{PJ,m} \times EF_{BL,e,CO_2} \quad (2)$$

And

$$EG_{PJ,m} = EG_{PJ} \times \left[\frac{\sum_p (FC_p \cdot NCV_p)}{\sum_p (FC_p \cdot NCV_p) + \sum_q (FC_q \cdot NCV_q)} \right] \quad (3)$$

Wherein: BE_e : Baseline emissions in power supply (tCO_2); $EG_{PJ,m}$: Grid electricity of the project activities, mainly from burning fossil fuels (MWh); EF_{BL,e,CO_2} : Powered baseline CO_2 emission factor (tCO_2/MWh); EG_{PJ} : Gross generating capacity in power plant project (MWh); FC_p : Power supply with total amount consumption of the P class fossil in power plant project (kg or m^3); NCV_p : Average net calorific value of P class fossil fuel in power plant by the project (GJ/kg or GJ/m^3); FC_q : The amount of Q class fossil fuels consumed by the project activity power (kg or m^3); NCV_q : Power supply with q class fossil fuel average net calorific value in power plant project (GJ/kg or GJ/m^3); p : Main fuel types of fossil fuels in power plant project; q : The type of fossil fuel as an auxiliary or startup phase used in power plants project.

$$EF_{BL,e,CO_2} = 3.6 \cdot \frac{\min(EF_{FF,BL,e,CO_2}; EF_{FF,e,CO_2})}{\eta_{BL,e}} \quad (4)$$

Wherein: EF_{BL,e,CO_2} : CO_2 emission factor on baseline (tCO_2/MWh); EF_{FF,BL,e,CO_2} : The CO_2 emission factors of power supply with fossil fuel (tCO_2/GJ) which most likely to be identified as baseline scenario; EF_{FF,e,CO_2} : Identified fossil fuel CO_2 emission factors (tCO_2/GJ) of the supply of

project activities; $\eta_{BL,e}$: Energy efficiency of power generation technology of baseline scenario, 3.6: The conversion factor from GJ to MWh .

The Development Methodology of Heating Part

1) The Calculation of the Emissions of the Project

Calculation the cogeneration project as follows:

$$\beta = \frac{HG_{PJ,m}}{EG_{PJ,m} \times 3.6} \times 100\% \quad (5)$$

Wherein: β : Ratio of heat to electricity; $HG_{PJ,m}$: Heating quantity of thermal power plants throughout the year (GJ); $EG_{PJ,m}$: On-grid energy generated by burned fossil fuel in project (MWh). Fossil fuel consumption is calculated as follows:

$$\sum FF_i = HG_{PJ,m} / (\eta_h \times NCV_i) \quad (6)$$

Wherein: FF_i : Heat supply with the total amount of the i-type fuel in the project (kg or m^3); NCV_i : unit net calorific value of i fuel (GJ/kg or GJ/m^3); η_h : Heating efficiency.

Based on IGCC technology, the heating part uses the the excluded waste heat in power generation process to heat the users, therefore, the CO_2 emissions is zero in the heating process of the project.

2) The Calculation of Baseline Emissions

The heating portion of the baseline scenario should be divided into two situations: the fossil fuel combustion scenario reference line and the electric heating scenario baseline. Hereby develop baseline methodology aiming at heating part in several cases.

A、Fossil fuel combustion scenario reference line

$$BE_h = FF_{BL,h} \times EF_{BL,h,CO_2} \quad (7)$$

Wherein: BE_h : The emissions in baseline heating process (tCO_2); $FF_{BL,h}$: The amount of fossil fuel consumed by heating in the project (kg or m^3); EF_{BL,h,CO_2} : The CO_2 emissions factor in baseline heating using fossil fuel (tCO_2/TJ);

B、The electric heating scenario reference line

$$BE_h = \frac{HG_{PJ,m}}{3.6 \times \eta_{BL,h}} \times EF_{e,CO_2} \quad (8)$$

Wherein: BE_h : The emissions in baseline heating process (tCO_2); $HG_{PJ,m}$: Thermal power plant heating

quantity all the year round (GJ); $\eta_{BL,h}$: The thermal efficiency of using electric heating mode without the project; EF_{e,CO_2} : Grid emission factor, selected by regional power grid line emission factor according to the National Development and Reform Commission(NDRC) (tCO_2 / MWh).

Participants in the project should use the following formula to calculate the emission reductions:

$$ER = BE_e + BE_h - PE_e \quad 9)$$

Wherein: ER : Project emission reductions (tCO_2); BE_e : Baseline emissions in supply process (tCO_2); BE_h : Baseline emissions in heating process (tCO_2); PE_e : Project emissions in supply process (tCO_2).

IGCC Power Plant CO₂ Emission Reduction Calculation

The Determination of Project Baseline

Power supply part of the baseline: construct conventional power plant and use coal as basic raw materials for power generation.

Heating part of the baseline^[3]: construct conventional heating plant and use coal as basic raw materials for heating generation.

Introduction of IGCC Project

We introduce the basic parameters of the project in order to calculate CO₂ emission reductions of the power plant^[4], shown in Table 1 at the bottom.

Calculation of CO₂ Emission Reduction

TABLE 2 CALCULATION OF CO₂ EMISSION REDUCTIONS ANNUALLY (UNIT: TCO₂)

CO ₂ emissions	Baseline emissions	Project emissions	Leakage	Emission reductions
Power part ^[6]	1,083,429	860,269	0	223,160
Heating part	240,875	0	0	240,875
Total	1,324,304	860,269	0	464,035

According to the data of the project, carbon dioxide emission reductions of the project can be calculated if we follow the formula above. Pointed out the IGCC power plant using waste heat generated in the power generation process for heating, therefore we do not consider carbon emissions produced by the power plant in heating part^[5], detailed data table is shown in Table 2.

IGCC Power Plant Environmental Benefits and Economic Benefits

IGCC Power Plant Environmental Benefits

According to the data of 250 MW IGCC power plant^[7], it can be calculated IGCC power plant save 227,763 tons coal per year, at the same time, according to saved coal, we can calculate the emissions reductions of SO₂, NO_x and smoke of IGCC power plant every year through the material scale algorithm, detailed data is shown in table 3.

TABLE 3 REDUCTION CALCULATION SHEET OF PROJECT POLLUTIONS (UNIT: T)

Pollutant	Baseline emissions	Project emissions	Leakage	Emission reductions
SO ₂ ^[8]	634.1	25.46	0	608.6
NO _x	4,143.7	2,496.1	0	1,647.6
Smoke	190.3	0	0	190.3

Economic Benefits Study of IGCC Power Plant

According to the data report, we can see the economic parameters of the project and detailed data is in the table 4.

TABLE 4 PROJECT ECONOMIC PARAMETERS

Parameters	Unit	Amount	Source
Total Investment	One hundred million yuan	25	Project owners statistics
Equipment life time	Year	25	Project owners statistics
O & M cost	One million yuan/year	249	Project owners statistics
CERS Price ^[10]	\$US/tCO ₂	7	China CDM information
Years of economic	One million yuan/year	800	Project owners statistics

According the data provided in table 4, whether with credit emission reductions (CERs) revenue or not,

internal rate of return (IRR) can be calculated in the service life of the equipment^[9], detailed data is in table 5.

TABLE 5 COMPARISON OF FINANCIAL INDICATOR IRR WITH AND WITHOUT CERS REVENUE

Parameters	Unit	Without CERS	With CERS	Benchmark IRR
IRR	%	15.59	16.32	12

During the period of running project, electricity and revenue are likely to change as the rising prices and energy shortages^[11]. Costs will increase because the system needs more maintenance with more usage rate, so set the revenue and the total cost of the project to the uncertain factor and sensitivity analysis was carried out on the project IRR. Sensitive data is in the table 6 and sensitivity analysis diagram is seen in Figure 1.

TABLE 6 SENSITIVITY ANALYSIS

Range of variation	-10%	-5%	0	5%	10%
Total static investment	17.30%	16.55%	15.59%	15.00%	14.23%
General income	13.12%	14.34%	15.59%	16.68%	17.43%
Total maintenance cost	16.12%	16.00%	15.59%	15.21%	14.87%

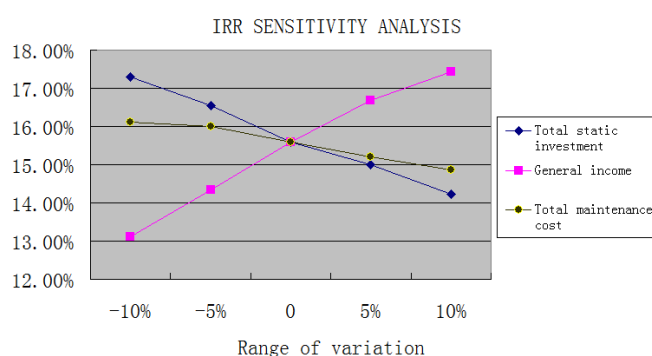


FIG. 1 SENSITIVITY ANALYSIS

The analysis^[12] shows that IGCC project compared with traditional coal-fired power plant, 227763 tons of coal was saved every year. Through economic analysis of project^[14], it can be seen obviously that its IRR is 15.59% without considering carbon trading and IRR is 16.32% considering the international carbon trading, were both higher than benchmark internal rate of

return whose IRR is 12%. Thus the project has great economic benefits in all respects^[13].

Summarizes

China vigorously advocates energy conservation and emission reduction and green travel. However, coal is important basic energy in China and the basic characteristics of China's energy resources is less gas, lean oil, rich in coal. Coal resource is more than 85% of the total reserves. Fossil fuels are mainly composed of coal in electric power industry. So vigorously develop new energy-efficient coal-fired power plants is particularly significant. This thesis is aimed at the advanced coal-fired power generation technology, namely the IGCC technology to discuss environmental benefits and economic benefits and use the development methodology to calculate carbon emission reduction as well as other pollutants by the heating portion of the IGCC plant^[15]. According to the calculation of 250MW IGCC plant, it can save 227,763 tons of coal, 464,035 tons of CO₂ emission, 608.6 tons of SO₂ emissions, 1,647.6 tons of NO_x emission and 190.3 tons^[10] of soot emissions per year. At the same time through analysis of the internal rate of return and the sensitivity analysis, IGCC has a strong economic attraction whose IRR is 16.32% in case of containing the environmental benefits. It can be seen that outstanding performance of IGCC power plant on the environmental and economic benefits is essential and advanced technology to the future development of electric power industry.

REFERENCES

- China CDM Information Center.
<http://www.china-cdm.org/home.htm>
- China's status of coal resource.
<http://wenku.baidu.com/view/614db8ed4afe04a1b071de06.html>.
- Chongtao Yang. "Pollution in the process of coal burning and development of deep processing of coal utilization technology". North Environment, 2011, (6):149-150.
- Gu Ye. "Analysis of power plant on energy conservation and emissions reduction". 2010(5):116-118.
- Haitao Liu, Xiaoyun Wang. "The promotion of thermal power industry's development strategy under the background of energy conservation and emissions reduction". 2012, 15(14): 79-81.
- Haiyong Bai, Jikun Fu. "Introduction of Integrated

- Gasification Combined Cycle (IGCC) power generation technology". Boiler manufacturing .2008 (3): 44-46.
- 《Heating network design specification》
- Le An."Analysis of thermal power plant on energy conservation and emissions reduction analysed in Liaoning province". 2011(7):113-115.
- Li Li, Chunju Dou, Haidong Xu. "Thermal power impact on the environment". 2006(3):66-67.
- Li Li, Wei Li, Weijian Yao. "Clean production is the inevitable choice of sustainable development of the thermal power industry". Guangdong Electric Power. 2003,16(3)18-21.
- Ming Li, Xiuwen Yang, Li Chen. "Saving energy and technical measures for thermal power unit". Shandong College Journals. 2009(1):54-59.
- Qinghua Yuan. "Reconstruction and evaluation research of cogeneration technology on energy saving and emission reduction". 2011:315.
- Wen Fu, Zhiwei Peng. "Thermal power generation and CDM". Science and technology in western China. 2008,32(7):37-38.
- Xing Jin. "Introduction to energy conservation and emissions reduction technology of coal-fired power plants". Shanghai Energy onservation.2008(6):08-10.
- Yongtao Lv, Chao Huang, Xiuqin Ma, Wanpeng Zhang. "Environmental Benefits Analysis of Centralized Heating Reconstruction Project". The Seventh International Green Building and Building Energy Efficiency Conference Proceedings". Existing Buildings Energy-saving Technology and Engineering Practice .247-249.

TABLE 1 250 MW POWER PLANT PROJECT PARAMETERS

Parameter	Unit	Value	Source
Project installed capacity	MW	250	Project owners report
Project power generation efficiency	%	48	Project owners report
Project running time	h	5000	Project owners report
Power generation efficiency of the baseline	%	35	Statistical data
The project generation owner-occupied rate	%	3	Project owners report
Project desulfurization efficiency	%	99	Project owners report
Project collection efficiency	%	100	Project owners report
Bituminous coal calorific value	GJ/Kg	0.02717	IPCC default values
Project heat-to-electric ratio	%	35	Heating network design specification